# Habitat Requirements for Freshwater Fishes

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| Complexity | Environmental Value | Cost |
| --- | --- | --- |
| Low Moderate High | Low Moderate High | Low Moderate High |

## OVERVIEW

With very few exceptions, stream restoration projects will have consequences for fish communities and the user groups associated with those communities. Water resource managers involved in stream restoration are a very diverse group. Some will have training in fishery science but most probably will not, and may have difficulty understanding some of the problems associated with fish habitat. This technical note is designed to help water resource managers who may have little or no training in fishery science to better understand problems associated with freshwater fish habitat.

An organism's habitat must contain all the physical, chemical, and biological features needed for that organism to complete its life cycle. For fishes this may include a variety of parameters such as water temperature regimes, pH, amount and type of cover, substrate type, turbidity, depth, water velocity, inorganic nutrient levels, and accessibility to migration routes. Habitat quality affects health of individual fishes, fish populations, and communities, and changes in habitat will usually result in changes to the species composition of a fish community.

Freshwater fishes are an extremely diverse group that have evolved to occupy a wide range of habitat types, some of which are extremely harsh environments for aquatic organisms. Some fish species can thrive under extreme conditions, including habitats that have been drastically degraded by anthropogenic causes. Such habitats often support a large fish biomass due to high levels of nutrients present in many polluted systems. Size of the fish biomass, therefore, is not necessarily a good indicator of habitat quality (Figure 1). Composition of the fish community can be a good indicator of fish habitat quality, as fish populations in degraded habitats are usually dominated by one or a few very tolerant species.

**Figure 1. Large fish biomass is not always indicative of quality habitat**

Another result of the diversity of freshwater fishes is that systems that have been so altered that they no longer provide habitat for some native fishes often provide ideal habitat for some very desirable game fishes. This can cause conflicts among management agencies or user groups who may have different opinions of what constitutes healthy fish habitat depending on how they perceive the resource.

For example, many large rivers in the United States have been extensively dammed to the

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detriment of large river fish species but to the benefit of some desirable game fishes. Sport fisheries on these altered systems often provide a substantial influx of currency to local economies. Some user groups and management agencies will perceive such altered habitats as good fish habitat because they provide quality recreational fisheries while others will perceive them as degraded because native species may be rare or absent.

Although an intensive assessment of fish habitat requires sampling of fish populations and measurement of physical habitat variables, less intensive surveys can often be accomplished by measuring selected water quality parameters and physical characteristics. Determining the necessary intensity level and deciding what variables should be measured will necessitate well-defined goals that researchers can use to accurately identify the problems so they can ask the proper questions. An accurate fish habitat assessment will require basic knowledge of the ecology of the system. Help in this area can often be obtained from state natural resource management agencies or one of the various federal natural resource management agencies, i.e., U. S. Fish and Wildlife Service, U. S. Geological Survey, Tennessee Valley Authority, U. S. Army Corps of Engineers, etc.

## IDENTIFYING POSSIBLE FISH HABITAT PROBLEMS

Some projects will require quantification of the overall ecological health of an aquatic habitat, which will probably require measurement of physical and chemical parameters as well as extensive sampling of the fish community. However, clearly defining the goals of the project and identifying potential fish habitat problems will simplify most fish habitat assessments. Many projects are concerned with one species or one aspect of fish habitat that is perceived to be deficient, such as protecting critical habitat of an endangered species, or increasing the amount of large woody debris in a stream. Defining specific goals of the project will help identify potential habitat problems and lead to specific questions that need to be answered by the habitat assessment. A basic understanding of the ecology of the system and knowledge of habitat requirements for individual fish species or species assemblages are required. Sources of information for some common fish habitat problems are given in Table 1. Examples of fish habitat problems, anthropogenic causes of these problems, and assessment questions to determine extent of the problems are given in Table 2.

**Table 1. Sources of Information to Solve Some Common Fish Habitat Assessment Problems**

| Information Required | Type of Information Available | Source |
|---|---|---|
| Habitat requirements for individual species | Specific habitat requirements and preferences for individual species, i.e., water quality, flow, substrate, depth, etc. | U.S. Fish and Wildlife Service 1982, 2000 |
| Water quality | In-depth discussion of all relevant water quality parameters | Boyd 1991 |
| Sampling fish populations | In-depth discussions of most techniques used assess exploited fish populations | Nielsen and Johnson 1983 |
| Fish passage, upstream migration | Design criteria for fish passage facilities | Katopodis 1991 |
| | Approximate cost of fish passage facilities | |
| | Formulas for calculating swimming performance of most freshwater fishes | |

**(Continued)**

Table 1. (Concluded)

| Information Required | Type of Information Available | Source |
|---|---|---|
| Fish passage, upstream and downstream migration | Design criteria for fish passage facilities | Bell 1986 |
| | Swimming performance of selected fish species | |
| | Discussion of downstream migration and barriers to downstream migration | |
| Entrainment of fishes | Design criteria for structures to minimize fish entrainment | Bell 1986 |
| | | Rainey 1985 |
| | | Pearce and Lee 1991 |
| Woody debris in lotic systems | Describes a method for quantifying amount of large woody debris in a stream | Wallace and Benke 1984 |
| | Describes methods for placing woody debris in small streams to enhance fish habitat | Seehorn 1985 |
| | Biological effects of removing large woody debris | Benke et al. 1985 |
| Spawning habitat | Description of spawning habitat for salmonid fishes | Bell 1986 |
| | Description of spawning habitat and strategies for a variety of freshwater fishes | Balon 1975 |
| Quantifying relative health of fish habitat | Instructions on how to develop an index of biotic integrity by sampling fish communities | Karr 1981 |
| | Describes how index of biotic integrity can be applied to a specific situation | Bramblett and Fausch 1991 |
| Tolerances of fishes to environmental stressors | Study comparing tolerance of some common fish species to environmental stressors | Whittier and Hughes 1998 |
| Temperature tolerance | Review of literature dealing with temperature tolerance and preferences of fishes | Jobling 1981 |

**Table 2. Examples of Common Fish Habitat Problems, Causes of the Problems, and Questions That Should Be Answered to Determine Extent of the Problems**

| Problem | Possible causes of the problem | Questions to be Answered to Assess the Problem |
|---|---|---|
| There may be a problem with fish migration | The most common structures that impede upstream fish migration are dams, weirs and culverts, but anything that increases flow velocity, decreases depth, or poses a physical barrier has the potential for impeding fish migration. Water diversions, physical barriers, or structures that reduce flow velocity can impede downstream migration | 1. Are migratory fish present in the system?<br>2. Are potential barriers present in the system?<br>3. What water velocities and depths are present at potential barriers? |

**(Continued)**

**Table 2. (Concluded)**

| | | |
|---|---|---|
| The stream may not have the correct temperature regime for a target species | Problems with high water temperatures are often the result of decrease in shade, decrease in water depth, or thermal effluents. Hypolimnetic discharge from an upstream reservoir is the usual cause of low water temperatures | 1. What is the upper temperature limit for the target species and does the maximum summertime water temperature exceed this limit? 2. Does the optimal range of summertime temperatures for the target species resemble the range of summertime temperatures for the stream? |
| Excessive sediment load may be adversely affecting a target species | Any factor that increases erosion in the stream channel or anywhere in the watershed can result in increased sediment loads. Common causes are channel modifications, clearing of riparian vegetation, logging activities, conversion of forest to agriculture, and road and bridge construction | 1. What are the upper turbidity limits of the target species, and are these often exceeded? 2. Does the target species require gravel or larger substrate for spawning and have these substrates been covered or are they in danger of being covered by sediments? |

## IDENTIFYING HABITAT REQUIREMENTS AND PREFERENCES FOR FRESH-WATER FISH SPECIES

A habitat requirement is some aspect of the habitat without which a species cannot survive over the long term. For example, water temperatures that do not exceed 24 °C and presence of gravel or larger substrate are two habitat requirements for most fishes of the family salmonidae (charr, trout, and salmon). If either of these requirements is not met, the population will go extinct. A habitat preference is some aspect of the habitat that a species will use out of proportion to its availability. For example, if a brook trout *Salvelinus fontinalis* has a choice between habitats with water temperatures of 5 °C and 15 °C it will most often chose the habitat with 15 °C water if all other factors are equal.

### Fish survey books

Fish survey books are a good starting point for locating information about habitat requirements and preferences for many fish species. Fish survey books are often published by state universities and usually have titles that begin with "Fishes of," "The Fishes of," and "Freshwater Fishes of," and thus can often be located with a title search. Fish survey books usually give very specific descriptions of appearance and physical characteristics of the different fish species and many also give a variety of life history and habitat data. However, often they are most valuable for the literature citations they contain that can lead to more specific habitat and life history information.

### Habitat models

Species profiles have been compiled and are a useful source of habitat information. Habitat suitability index (HSI) models are another useful source of habitat information for a number of freshwater fish species. HSI models can also be used to quantify the suitability of a habitat for a particular species, thus allowing comparison of different streams. Like fish survey books, species profiles and HSI models

are valuable for the well-documented references they contain, which are very useful for in- depth studies of fish habitat requirements.

**Peer-reviewed literature**
Peer-reviewed journal articles will generally contain the most specific and accurate information concerning habitat requirements and preferences. However, locating information for a specific habitat characteristic or species may be difficult.

**Knowledge gaps**
Specific habitat requirements and preferences and specific life history data are lacking for most North American fishes. Therefore, determining habitat requirements of species assemblages will usually require selecting and researching the requirements for a few key species about which something is known. When feasible, representatives of each trophic level should be chosen for this analysis.

## FISH HABITAT REQUIREMENTS AND HABITAT RESTORATION

Many efforts to improve fish habitat have failed because little was known of habitat requirements of target species or species assemblages. Proper assessment of fish habitat and accurate information of fish habitat requirements will help managers determine factors that are lacking so they can design effective restoration projects. Unfortunately, habitat requirement information is unavailable for many fishes, and as a result, many species are imperiled due to habitat deficiencies that cannot be specifically identified. When working with such species, the best approach is to attempt to restore all the physical parameters of unaltered habitat. This will probably require extensive habitat assessment and some guesswork.

## A BRIEF DESCRIPTION OF FRESHWATER FISH HABITAT: LOTIC SYSTEMS

Lotic habitats are those with a regular measurable velocity (i.e., usually natural streams, but also some artificial waterways).

**Water velocity**
Fishes occupy habitats ranging from waterfalls to stagnant pools, but a given life stage of a given species will tend to prefer a relatively narrow range of velocities. Water velocity preferences vary among the species that make up a stream community, and thus, a diversity of water velocity is generally desirable for fish habitat. Spatially uniform velocities characterize relatively poor fish habitat.

In most cases, a velocity regime that is nearest to the unaltered state for the stream will provide the best habitat for the native fish assemblage. Regulated rivers with flow velocities that vary from near zero to very high on a daily or hourly basis can be extremely detrimental to fish communities. Spatial, rather than temporal, diversity should be optimized in any project design.

**Temperature**
Freshwater fishes can be divided into three categories based on temperature requirements. Coldwater fishes have an upper lethal limit of approximately 25 °C. All members of the families Salmonidae (charr, trout and salmon), Osmeridae (smelts) and Cottidae (sculpins) and various species of other families, can probably be classified as coldwater fishes. Warmwater fishes can tolerate water temperatures as high as 36 °C and thrive in temperatures that would quickly kill coldwater fishes. Examples of common warmwater fishes include largemouth bass *Micropterus salmoides*, bluegill *Lepomis macrochirus*, black crappie *Pomoxis nigromaculatus*, and channel catfish *Ictalurus punctatus*. The third category is coolwater fishes. There is no rigorous definition of coolwater fishes or coolwater habitat, but generally, coolwater fishes have similar or slightly lower upper lethal temperature limits than warmwater fishes but require cooler average temperatures during the growing season. Some common coolwater fishes include northern pike *Esox lucius*, walleye *Stizostedion vitreum*, and smallmouth bass *Micropterus dolomieui*. Temperature preference and requirement data for some common fish species are given in Table 3.

Coolwater fishes (and possibly coldwater fishes) sometimes take advantage of

microhabitats that allow them to live in warmwater habitats. This, and the fact that temperature requirement and preference data are lacking for most fish species, often makes categorization based on temperature requirements difficult.

Changes in mean or peak water temperatures can greatly alter the species composition of a stream. Most water temperature problems involve increased water temperatures that can destroy coldwater habitat and eliminate less tolerant species from warmwater habitat. This can be very serious due to the high sport and commercial value of many coldwater species, and decreased diversity of a coolwater species from loss of stocks specifically adapted to certain warmwater habitats. Reasons for increased water temperatures in streams include thermal effluents, loss of shade due to reduction of riparian vegetation, and decrease in depth from erosion or reduction in flow.

Decreased water temperatures are usually the result of hypolimnetic discharge from reservoirs. The effect is usually confined to the immediate reach downstream from the dam and it is not usually a serious problem unless highly endemic fishes are present.

**Table 3. Temperature Requirements and Preferences for Select Fish Species**

| Species, Life Stage | Upper Limit(°C)[1] | Optimum Range(°C)[1] |
|---|---|---|
| Lake trout | 23.5 | 4 - 18 |
| spawning | n/a | 4.5 - 14 |
| Brook trout | 20.1 - 25.3 | 11 - 16 |
| spawning | n/a | 4.5 - 10 |
| Brown trout | 23 - 26.4 | 12 - 19 |
| spawning | 27 | 2 - 13 |
| juvenile | 27 | 7 - 19 |
| Atlantic salmon | 23 | 12.1 - 15.1 |
| spawning | n/a | 5.0 |
| egg protection | 12.0 | 6.0 |
| Coho salmon | 25.5 | 4.0 - 14.0 |
| juvenile | 25.0 | 4.4 - 9.4 |
| spawning | 25.8 | 6.0 - 12.0 |
| egg protection | n/a[2] | 4.4 - 13.3 |
| Chinook salmon | 25.1 | 11.7 - 15.5 |
| spawning | 16 | 5.6 - 10.6 |
| egg protection | 16 | 5.0 - 14.4 |
| Sockeye and Kokanee salmon | 22 | 5 - 17 |
| juvenile | 18 | 11-15 |
| spawning | 10 | n/a |
| egg protection | 13 | n/a |
| Chum salmon | 23.7 | 8.3 - 15.6 |
| juvenile | 23.8 | 12.0 - 14.0 |
| spawning | n/a | 7.2 - 12.8 |
| egg protection | n/a | 4.4 - 14.0 |
| Pink salmon | 25.8 | 5.6 - 14.6 |
| juvenile | n/a | n/a |
| spawning | n/a | 7.2 - 12.8 |
| egg protection | n/a | 4.4 - 13.3 |
| Cutthroat trout | 22.0 | 9 - 12 |
| spawning | n/a | 6 - 17 |
| eggs | n/a | 10 - 11 |
| juveniles | 21 | 11 - 21 |

**(Continued)**

**Table 3. (Concluded)**

| Species, Life Stage | Upper Limit(°C)[1] | Optimum Range(°C)[1] |
|---|---|---|
| Rainbow trout & steelhead | 25 | 12 - 18 |
| spawning | n/a | 10 - 15.5 |
| Northern pike (summer) | 28.4 - 34 | 24 - 26 |
| spawning | 11 | n/a |
| Carp | 35.7 - 40.6 | 29 - 32 |
| spawning | 21 | 16 - 20 |
| Emerald shiner | 30.7 - 35.2 | 25.1 - 27.8 |
| spawning | 24 | n/a |
| Longnose sucker | n/a | 10 - 15 |
| spawning | n/a | 10 - 15 |
| Channel catfish (summer) | 36.1 - 36.4 | 29.0 - 30.5 |
| spawning | 27 | 21 - 29 |
| Smallmouth bass | 35 | 26 - 31.3 |
| spawning | n/a | 12.8 - 21 |
| Spotted bass | 36 | 29 - 30.8 |
| spawning | n/a | 18 - 21 |
| Largemouth bass | 36.4 | 25 - 32 |
| spawning | 30 | 21 |
| Black crappie | <36 | 19 - 24 |
| spawning | 18 | 15 - 18 |
| Bluegill | 35.5 – 37.3 | 29 - 32.3 |
| spawning | >27 | >25 |
| Anadromous striped bass | 27 | 16 - 25 |
| spawning | n/a | 17 - 19 |
| White bass | n/a | 19 - 28 |
| spawning | n/a | 15.5 - 16.7 |
| Walleye | 31.6 | 22.1 - 23 |
| | n/a | >10 |
| Sauger | 30.5 | 21.3 - 22.6 |
| | n/a | >5.6 |

[1]Unless indicated, limits and ranges are for adults (migrating adults for anadromous salmonids).
[2] n/a - not available

**Depth**
Optimal depth is usually species- and life-stage dependent. Some species require shallow areas, some require deep areas, and some, such as Gulf sturgeon, *Acipenser oxyrinchus desotoi*, appear to require a wide range of depths. Generally, a wide range of depths is desirable for fish habit. Low-order streams should have shallow riffle areas interspersed with deeper pool areas while high-order streams should have a variety of shallow sandbar or gravel bar habitat interspersed with deep holes.

**Instream Cover**
Instream cover, usually in the form of boulders or large woody debris, can provide habitat for invertebrates, velocity refuges, hiding places from predators, and attachment sites for adhesive fish eggs. Because depth and velocity of flow are closely related to certain types of cover features, maximizing cover often increases diversity in depth and velocity. Instream cover is an important component of most lotic habitats and generally, more instream cover means better fish habitat.

## Stream Size

Lotic systems are often classified according to order. A first-order stream has no tributaries, is usually small and is often intermittent. The confluence of two first-order streams creates a second-order stream and the confluence of two second-order streams creates a third-order stream. Usually, low-order streams have relatively high gradients, large substrate, high water velocity, and few fish species compared to higher-order streams (Figure 2). However, some of the most culturally and economically important species occur primarily, or only, in low-order streams. Thus, small stream habitat may be a very important component of the fish habitat of a region.

**Figure 2. Low-order, high-gradient streams usually have few fish species and small biomass but are still important fish habitat**

Fishery and fish habitat investigations are usually easier to successfully conduct in lower order than in high-order streams. Low-order streams are usually less turbid and shallower, which makes them easier to sample and also makes it less difficult to determine specific microhabitats that fishes occupy during different phases of their life cycles.

High turbidity, high flows, deep water, and commercial barge traffic make high- order streams and rivers difficult, and sometimes dangerous, environments in which to sample fishes. It is also more difficult to determine specific microhabitats used by fishes in large rivers than in small streams.

Difficulty in sampling large river habitats is illustrated by the lack of knowledge of habitat requirements of many fishes that utilize large rivers. For example, the sturgeons (family Acipenseridae) utilize large river habitat and have been studied extensively, but specific habitat requirements are largely unknown for most stocks.

**Figure 3. High water velocity, high turbidities, deep water, and barge traffic make the lower Mississippi River a difficult habitat to sample**

## Substrate Size

As a general rule, substrate size decreases with increasing stream order, with substrate in the largest rivers usually consisting of sand, silt, and clays. Many fishes, including some culturally and economically important species, cannot reproduce successfully unless gravel or larger substrate is available. Thus, gravel and larger substrates are often very important habitat components.

## Instream Vegetation

Instream vegetation can be an important component of fish habitat in lotic systems, especially those with relatively low water velocity and fine substrate. Instream vegetation can provide the same benefits as instream cover; however, an overabundance of aquatic vegetation can lead to low dissolved oxygen levels and problems with predator/prey relationships. Excess aquatic vegetation can also interfere with flood management, navigation, and recreation. As a general rule, native aquatic plant species are desirable and introduced species are not. Most problems with excessive aquatic vegetation involve introduced species.

**Riparian Vegetation**
Riparian vegetation (Figure 4) is very important for the health of many lotic habitats. Riparian vegetation increases bank stability, reduces sedimentation, reduces summer water temperatures, and increased recruitment of large woody debris. Deposition of leaves and other organic matter from riparian vegetation is an important source of nutrients for many low-order streams. Riparian vegetation can absorb nutrients from agricultural and urban runoff and thus mitigate some negative impacts to nutrient-rich habitats. Riparian vegetation is also an essential component of the formation of important habitat components such as pools and undercut banks.

**Figure 4. Riparian vegetation is an important component of stream habitat**

**Floodplain Habitat**
Many fish species require floodplain habitats for successful reproduction and some utilize floodplains during all phases of their life cycles. Healthy floodplains serve as nutrient and sediment sinks resulting in improved water quality in the stream. Healthy floodplains also attenuate flows and lessen the magnitude of floods and water receding from floodplains often contains a substantial amount of food utilized by stream fishes.

Clearing floodplain habitat for agricultural or other uses often causes excessive sedimentation and turbidity, excessive nutrient inflows and associated problems with water quality, and reduced reproductive success of some fish species. As a general rule, if a stream had extensive floodplain habitat in its pristine state, alterations to or reduced access to floodplain habitats will probably degrade fish habitat. Because floodplains act as sediment traps, alterations that increase sedimentation and turbidity in the stream often adversely impact floodplain habitat.

**Fish Migration and Blockages to Migration**
Although migratory fish species may be a small component of fish assemblages in lotic habitats, these species are often among the most economically and culturally important. The most common structures that impede upstream fish migration are dams, weirs, and culverts; however, anything that increases flow velocity, decreases depth, or poses a physical barrier has the potential to impede fish migration (Figure 5). Water diversions, physical barriers, or structures that reduce flow velocity can impede downstream migration. Barriers to fish migration are classified as total, blocking all migration all of the time, or partial, blocking all migration some of the time, or some migration all of the time. In most cases, barriers to fish migration degrade fish habitat.

**Figure 5. Even low head dams can be detrimental to migratory fishes such as this Gulf sturgeon**

**Water Quality**
Dissolved oxygen: As a general rule, a dissolved oxygen level of less than 3 ppm in warmwater streams, or less than 5 ppm in coldwater streams, is cause for alarm. Because water in lotic habitats is moving and is usually not stratified, low dissolved oxygen is not a problem as often as it is in lentic habitats. However, low dissolved oxygen can be a problem in tailraces of hydropower dams with hypolimnetic discharge, in slow-flowing streams with excess nutrients, or in streams

with excessive submersed or floating aquatic vegetation. Dissolved oxygen levels are usually lowest during early morning hours and should be measured at that time.

Total alkalinity: Total alkalinity in natural systems can range from less than 5 ppm to more than 500 ppm $CaCO_3$. As a general rule, total alkalinity greater than 20 ppm $CaCO_3$ provides adequate buffering against shifts in pH, to provide good fish habitat. Streams with very low total alkalinity may be especially susceptible to acid from point sources or acid precipitation.

Turbidity: Suspended sediments, concentration of humic substances, phytoplankton, and industrial discharge can cause turbidity in lotic habitats. Generally, relatively low turbidity (i.e., less than 20 NTU) is best for fish habitat in lotic habitats.

Most turbidity in lotic habitats is due to suspended sediments. Some turbidity due to suspended sediments is normal in many lotic systems; however, excessive levels of suspended sediments can be extremely harmful to aquatic habitats and fish populations. Turbidity from humic substances is a natural condition for many coastal plain streams and is usually indicative of healthy fish habitat from a standpoint of native fish biodiversity. However, such systems are usually not very productive and may not withstand fish harvest. Excessive turbidity due to phytoplankton is rare in lotic systems but is most common in high-order, slow-moving streams and is usually indicative of excessive nutrients. Turbidity from industrial discharge is rarely a desirable condition in any aquatic habitat; however, point discharges from industry that cause a visible effect are usually tightly regulated by state and federal environmental protection agencies.

## A BRIEF DESCRIPTION OF FRESHWATER FISH HABITAT: LENTIC SYSTEMS

A lentic habitat is one in which water does not have a regular, measurable flow. Lentic habitats include natural lakes, small impoundments, parts of most mainstem reservoirs, some low-gradient natural streams, and some canals. Unlike lotic habitats, the water column in most lentic habitats thermally stratifies. Most lentic habitats in the United States are either monomictic (i.e., the water column stratifies during warm months and mixes during cool months) or dimictic (i.e., the water column stratifies during the warm months and during cold months and mixes during the spring and fall). In a stratified water column, the upper layer (epilimnion) is separated from the lower layer (hypolimnion) by a transitional layer called the thermocline. The interaction of a stratified water column and water quality, especially dissolved oxygen, has profound effects on the fish community.

In general, habitat preferences and requirements for fishes in lentic habitats are similar to those for lotic habitats. Exceptions follow.

**Water Quality**

Turbidity: Turbidity in lentic systems is usually due to phytoplankton. These organisms also form the basis of the food chain and usually play a major role in the oxygen balance of the system. The amount of turbidity from phytoplankton that is acceptable should be determined by an individual who is knowledgeable in local conditions and fish assemblages.

Systems with turbidity from humic substances are usually dystrophic and will not be able to withstand high harvest of sport or commercial fishes. However, this condition is natural for many southeastern coastal plain water bodies and can be considered indicative of good habitat for native fish communities. High turbidity from suspended inorganic solids is not normal for most lentic systems and is usually indicative of poor fish habitat.

Dissolved oxygen: Dissolved oxygen in lentic habitats is usually tied to photosynthesis and respiration of algae and submersed vascular plants. Most problems with low dissolved oxygen are the result of an overabundance of plants caused by excess nutrients. In extreme cases, dissolved oxygen levels will be above the saturation level after several hours of sunshine but will be near zero after several

hours of darkness. Shifts in dissolved oxygen levels will be most extreme during the warmest part of the year when plant respiration and photosynthesis are greatest and solubility of oxygen in water is lowest.

When the water column becomes stratified, the hypolimnion may become anoxic if turbidity is too high to allow sufficient light penetration. Although this condition has the potential for causing fish kills when the water column mixes, it is normal in many systems and does not necessarily indicate poor fish habitat.

Inlet and outlet streams: Inlet and outlet streams play an important role in reproduction of certain fish species in lentic habitats. Reduced access to, or alteration of inlet and outlet streams can severely impact fish communities in natural lakes. Further, fishes that spawn in inlet and outlet streams are often economically and culturally very important. Examples of such species are walleye (*Stizostedion vitreum)*, Atlantic salmon (*Salmo salar)*, Pacific salmons (*Oncorhynchus* sp.), arctic grayling, (*Thymallus arcticus)*, and lake sturgeon (*Acipenser fulvescens)*.

Inlet streams can also be important in reservoirs. The amount of free-flowing river at the upstream end of a reservoir may determine whether riverine species can survive impoundment. A long, free-flowing section of river above a reservoir may ensure preservation of the natural biodiversity of fishes in the system.

## EXCEPTIONS TO THE BASIC RULES

Freshwater fishes have evolved to fill almost every type of freshwater environment. In some cases, these habitats are naturally very harsh and do not fit the general description of desirable fish habitat. A good example is the Colorado River drainage in the southwestern United States that, in its natural state, had very high turbidity due to suspended sediments and very little riparian vegetation. Regulated flows have lowered turbidity, allowed riparian vegetation to become established, and allowed establishment of nonnative fishes, much to the detriment of the native fish community.

Another example is floodplain lakes in the Lower Mississippi Valley. These lakes have silt and mud substrates, often have high sediment turbidity and low dissolved oxygen, but still provide good habitat for native fishes that have adapted to the harsh conditions. These are only two of the many examples of habitats that in their pristine state do not fit the general model of desirable fish habitat.

## ALTERED HABITATS AND INTRODUCED SPECIES

Many freshwater habitats have been altered to the point that maintaining the native fish assemblage is not feasible. However, some of these habitats may be ideal for economically and culturally important fishes and in some cases stocking fish species that are not native to the system will increase recreational opportunities. Examples include small impoundments, reservoirs, and tailraces of some mainstem reservoirs. Small impoundents are often constructed and managed specifically for commercial or recreational fishing. Natural resource agencies of most states can aid with design and management of small impoundments to provide optimal habitat for the desired fish assemblage. Mainstem reservoirs are usually colonized by native fishes, with no need for supplemental stocking. However, reservoirs can sometimes support nonnative species that could not survive in the unimpounded river and may be desirable for recreational fishing. Likewise, tailraces of some mainstem reservoirs with hypolimnetic discharge provide habitat for recreationally important coldwater fishes that otherwise could not survive in the region.

Nonnative fishes are sometimes stocked to improve quality of aquatic habitats. The best example is probably grass carp *Ctenopharyngodon idella*, an herbivorous fish that is often stocked to control nuisance aquatic vegetation. Economic and environmental cost and benefits of stocking nonnative species in altered habitats should be carefully weighed before any action is taken. Likewise, assessments should be performed during and after the stocking program to determine if goals

have been met and to adjust stocking rates to maximize benefits and minimize impacts.

## FISH SAMPLING TECHNIQUES

Humans have been searching for better ways to catch fishes since before recorded history. Many, if not most, of the techniques developed over the centuries have been used, and continue to be used, by fisheries workers in their unending search for an unbiased method of sampling fish populations. One of the most comprehensive discussions of fish sampling techniques is given in "Fisheries Techniques," published by the American Fisheries Society, Bethesda, Maryland. Some of the most common fish sampling techniques are given in Table 4.

**Table 4. Some Common Gear Types Used to Sample Fish Populations**

| Gear Type | Habitats Usually Sampled |
|---|---|
| Passive nets | |
| Gill nets | Large lentic systems |
| Hoop nets | Large lotic systems |
| Traps | Most freshwater habitats |
| Active nets | |
| Larval fish tows | Lenthic and low gradient lotic habitats |
| Small seines | Small lentic and lotic systems |
| Large seines | Large lentic habitats |
| Trawls | Large lentic systems and large low gradient lotic habitats |
| Electricity | |
| Boat-mounted | Lentic and low gradient lotic habitats |
| Backpack | Small lotic systems |
| Toxicants | |
| Rotonene | Warmwater systems, lentic and small lotic systems |

## SUMMARY

Freshwater fishes have evolved to occupy most freshwater habitats, some of which are naturally very harsh. This diversity allows freshwater fishes to occupy habitats that have been greatly altered and allows some altered habitats to support important recreational fisheries.

Fish habitat assessment can be simplified by carefully examining project goals and anticipating potential habitat problems. Adequate assessments can often be accomplished by measuring certain water quality parameters and physical attributes such as, substrate size, amount and type of instream cover, amount and type of riparian vegetation, flow regimes, and stratification regimes. A wide range of values can provide quality fish habitat in most regions, however, specific, well-stated project goals will probably considerably narrow the range of acceptable values and will probably simplify the design process.

In some cases, quality habitat for target species and fish assemblages will bear little resemblance to habitat for popular game species that have traditionally received the most attention from managers.

## APPLICABILITY AND LIMITATIONS

This technical note was designed to help water resource managers who are not trained in fishery or fish biology to understand problems associated with fish habitat. A detailed description of freshwater fish habitats of any one of the 50 states could easily occupy volumes. This technical note describes North American freshwater fish habitats and is therefore, generalized.

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